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Waves in Plasma Sheaths and at Boundaries: Theory and Computer Experiments

AASERT Annual Progress Report
July 1, 1994 -June 30,1995

Charles K. Birdsall, Principal Investigator
Keith Cartwright, Graduate Student Researcher

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AASERT Progress Report (7/1/94 - 6/30/95)

Keith Cartwright, Graduate Student Researcher,

Electronics Research Laboratory,

University of California, Berkeley

This is a description of the work Keith Cartwright has done as a graduate student in the last year supported by an AASERT in Professor C. K. Birdsall's Plasma Theory and Simulation Group. The three main areas of research are: (1) the reflection of ion waves from the sheath, (2) crossed-field diodes, and (3) the development OOPIC.

1. The goal of this work is to find the mechanism in the presheath, sheath, and wall region that reflect, transmit, and absorb ion acoustic waves. Ion waves are observed to propagate from the bulk plasma into and completely through the sheath to the wall. These waves have a frequency less than the ion plasma frequency. Ion waves have been purposely launched as well as spontaneously generated by an ion acoustic instability. This instability is due to relative drifts of warm electrons and cool ions in the presheath. Our one and two dimensional PIC simulations show the details of densities, potentials, fields, velocity moments and time-distance plots of the average density minus the instantaneous density. The density perturbation shows the waves partially reflected before they reach the sheath edge. The goal of this work is to find the mechanism that reflect ion acoustic waves.

2. In cross field diode simulations we are looking for 2d effects to contrast with 1d results already obtained. This investigation indicates the transverse dimension is important in delaying the onset of virtual cathode oscillations for currents above the limiting current. The work so far has been limited to the behavior of the diode at $B = B_{Hull}$; this will be extended to regions of larger magnetic fields.

3. The object here is to complete the OOPIC (or, PIC++) computer simulation program, a particle-in-cell, cylindrically symmetric, electromagnetic model of an electron beam in a slow or fast waveguide, or a plasma. This program is written in C++, using an

object-oriented design philosophy. Most of this work has been done in collaboration with Dr. John Verboncoeur. Our accomplishments are:

(a) The physics kernel of the OOPIC code on the UNIX environment (XOOPIC) has been kept current with the physics on the PC platform. The UNIX version has aided in verifying the accuracy as well as discovery and correction of problems with the physics kernel.

(b) A nonlinear Boltzmann electron field solver has been added to the OOPIC code. The code is now capable of simulations in the region where ion effects are dominant. It is important to extend the usefulness of OOPIC from high frequency electromagnetic models and electron dominated electrostatic system to the domain where low frequency ion dynamics are dominant.

(c) A Markov Chain Monte Carlo method for loading a simulation initial specify densities, f(**v**) and n(**x**). These forms must be inverted in order to obtain the phase space positions, **x** and **v** of the particles.

(d) A flexible electromagnetic boundary condition has been added. This boundary can be used to model a general impedance wall, lossy conductors, or a free space boundary condition.

(e) A boundary condition has which launches electromagnetic energy into the system has been added so an input waveguide can be modeled.

The following is a list of abstracts of presentations made:

1. One Dimensional Investigation of Ion Acoustic Waves[1]

K.L. Cartwright and C.K. Birdsall

Ion waves are observed to propagate from a grounded plasma into and completely through the sheath to a floating wall. The above model is equivalent to a floating plasma and a grounded wall. These waves have a frequency less than the ion plasma frequency. They appear to be generated by an ion acoustic instability, probably due to relative drifts of warm electrons and cool ions in the presheath. Our one dimensional PIC simulations show the details of densities, potentials, particle moments and time-distance plots of the average density minus the instantaneous density. The latter points out that the waves partially reflect before they reach the sheath edge, where charge separation begins. The sheath's characteristics (and hence the sheath waves) depend on the particle sources. Therefore, the results from a planar ionization source (Q-machine), uniform ionization, and ionization proportional to electron density will be examined. Our observations will be compared with laboratory experiments and theory, which all have different results.

[1] American Physical Society Division of Plasma Physics, November 1994, Minneapolis, Minnesota.

2. Two Dimensional Investigation of Ion Acoustic Waves Reflection from the Sheath[2]

K.L. Cartwright and C.K. Birdsall

Preliminary results show that oblique ion waves propagate from the bulk plasma into and all the way through the sheath in both 1D and 2D simulation. These waves are launched from one side of the system with a AC voltage or a current source with a frequency less than the ion plasma frequency. Our one and initial two dimensional PIC simulations show the details of densities, potentials, fields, particle moments and time–distance plots of the average density minus the instantaneous density. From the time–distance plot the direction and magnitude of the ion acoustic wave is measured. From this the coefficients of reflection and transmission as a function of the incident angle is calculated. Our observations will be compared with laboratory experiments and theory.

3. Transverse Asymmetry in a Crossed – Field Diode [3]

K.L. Cartwright, J.P. Verboncoeur, V.P. Gopinath and C.K.Birdsall

Recent studies of cylindrical crossed-field diodes indicate the transverse dimension may play a role in delaying onset of virtual cathode oscillations for currents above the limiting current. Transverse space charge effects in smooth diodes can result in fields which warm the electrons. Thermal emission of electrons damps virtual cathode oscillations, as shown by Birdsall. The effects of the transverse dimension are explored using two-dimensional planar PIC codes.

[2]IEEE International Conference on Plasma Science, June 1995, Madison, Wisconsin.

[3]First International Crossed Field Diode Workshop, August 1995,Ann Arbor, Michigan.